

METHOD AND APPARATUS FOR SOFTWARE FEATURES
SYNCHRONIZATION BETWEEN SOFTWARE SYSTEMS

"Cross-Reference to Related Applications"

at

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to software systems particularly with respect to coordination of software feature installation in separate software systems.

2. Description of the Prior Art

Computer systems normally include plural separate software systems exemplified by the System Software (including the Operating System (OS), System Libraries and Utility programs), Application software (including OEM as well as user), and for some Medium to Large Scale systems, Special Purpose Processor (SPP) microcode. An example of an SPP would be the Task Control Unit (TCU) and I/O Unit (IOU) which are part of the I/O Module (IOM) on some of the A-Series and ClearPath systems manufactured by Unisys Corporation of Blue Bell, Pennsylvania (e.g. A18, NX4800).

The IOU is a logical component of the IOM responsible for managing I/O requests sent by OS software. The TCU is the logical component of the IOM responsible for managing task switching and events. In such computer systems there is generally a problem with respect to the release and/or installation of such software systems (e.g., OS software and SPP microcode).

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Normally, the release and/or installation of OS software and SPP microcode can occur independently.

1 If, however, one or more newly added system features
require OS software and SPP microcode functionality,
problems arise in the coordination of release and
installation of the separate software systems. The
5 coordination effort is further complicated when the
release and installation procedures differ.

With respect to release problems, it is more
often than not, that OS software development and SPP
microcode development are performed by different
10 engineering groups. These groups develop release
procedures, release identification methods, release media,
project schedules and the like, that best satisfy their
requirements. Because of the inherent differences between
the development of high-level OS software compared to
15 SPP specific microcode, the release mechanisms are seldom
the same.

Whenever a new system feature is introduced
requiring new releases from both the OS software and
the SPP microcode, the following constraints must be
20 considered.

1. The release dates for both the OS software
and SPP microcode must be the same. Since
software and microcode are independently
developed, no advantage is achieved by the
25 early completion of either the OS software
or the SPP microcode.
2. The release of additional new features that
are unique to either the OS software or SPP
microcode must be delayed until both releases
30 are ready.
3. The release of problem fixes that are unique
to either the OS software or SPP microcode
are delayed until both releases are ready.
4. Regression testing is delayed until both
35 releases are ready.
5. Individual release documentation is
complicated by the addition of release

1 interdependency descriptions.

With respect to installation problems, it is not unusual for OS software and SPP microcode installation procedures to differ. Systems often allow OS software
5 and SPP microcode to be independently installed. System interruptions are minimized if only one or the other requires a new support release to be installed. Whenever a new system feature is introduced and that feature requires new releases from both the OS software and SPP
10 microcode, the following installation constraints must be considered.

1. If release interdependencies are not properly documented or are misinterpreted by those responsible for the installation, the wrong
15 release levels may be installed or interdependent releases may be omitted. This may result in longer system interruptions and potentially require that a previously installed release be backed out until the interdependent release is obtained.
2. Even though an installation completes successfully, if an interdependent release was omitted, it may not be immediately detected. The system will resume normal
20 operations until the new system feature is invoked.
3. Release and installation of OS software and SPP microcode must be coordinated whenever one or more mutually supported system features
25 are added.
- 30

Although the above problems were described in terms of OS software and SPP microcode, it is appreciated that these problems arise in any system that includes a plurality of separate software entities required to
35 support a particular new feature. Similarly, the below-described invention, that solves the problems, although explained in its best mode embodiments with

1 specific software entities, it is appreciated that the
invention is applicable to any plurality of software
entities required to support a system feature.
Specifically, the invention will be described in terms
5 of OS software and SPP microcode such as a TCU for an
IOM. In the Unisys Corporation A-Series computer systems
the OS is referred to as a Master Control Program (MCP).
The invention may also be applied to the MCP and an IOU
for the IOM.

10 Additionally, the invention may be applied between
OS software and a System Library, between two user
applications or between any independent software entities
capable of exchanging data in the manner to be described
by its best mode embodiments.

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SUMMARY OF THE INVENTION

The invention includes an interface and protocol
between first and second software entities of a system
(e.g., OS software and SPP microcode) for the exchange
20 of indications of system features requiring mutual
support. During the exchange process, each software
environment (e.g., OS or SPP) will examine the other
environments supported features to determine which
features are mutually supported and therefore usable.
25 The interface is preferably utilized during system
initialization and prior to use of such features. If
a feature is not mutually supported, appropriate action
is taken. If the non-supported feature is optional,
it will not be enabled. If the feature is required,
30 the system will report the error and/or halt.

The following new enhancements are provided by
the mechanism of the present invention.

- 35 1. Optional and required system features may
be developed and released independently by
software development groups such as the OS
and SPP development organizations.
2. Support releases, for example, OS or SPP,

- 1 (which may contain bug fixes) may now include
new optional and required feature support
without the need to synchronize such releases.
3. Incompatibility resulting from feature content
5 between OS and SPP releases is immediately
detected and reported by the OS during
initialization.

BRIEF DESCRIPTION OF THE DRAWINGS

10 Figure 1 is a schematic block diagram of a
computer system in which the present invention is
embodied. Figure 1 is illustrated in terms of OS and
TCU software entities.

Figures 2(a) and 2(b) are the MCP procedure
15 declaration for the TCU_EXCHANGE_FEATURES function of
Figure 1 and the parameter definitions thereof,
respectively.

Figure 2(c) illustrates the manner in which the
parameters of Figure 2(b) are set up for the function
20 call via the hardware 14 and 15 shown in Figure 1.

Figures 3(a) and 3(b) comprise a flow chart
describing how the interface of the present invention
is used in the environment of Figure 1.

Figure 4 is a pseudo code description of the
25 feature exchange mechanism of the present invention.
The pseudo code description of Figure 4 functionally
corresponds to the flow chart of Figures 3(a) and 3(b)
but using the more general OS and SPP nomenclature.

DESCRIPTION OF THE PREFERRED EMBODIMENT

30 Referring to Figure 1, a computer system 10 is
schematically illustrated embodying the present invention.
Specifically, the computer system 10 may utilize a 48
bit word and may be embodied by an A-Series computer
35 system available from Unisys Corporation of Blue Bell,
Pennsylvania. The computer system 10 includes an
Operating System (OS) 11, otherwise denoted as a Master

1 Control Program (MCP) running on one or more Instruction
Processors (IPs) 17. The designations OS and MCP will
be used herein interchangeably. The computer system
10 further includes an Input/Output Module (IOM) 12 for
5 communicating with peripheral devices in a well-known
manner. The IOM 12 includes a Task Control Unit (TCU)
18 which is responsible for managing task switching and
events. The TCU 18 is a Special Purpose Processor (SPP)
controlled by TCU microcode 13. Throughout the
10 description herein, the designations TCU and SPP will
be used interchangeably and will denote hardware or
microcode or both in accordance with the context.

The IP 17 and IOM 12 provide hardware support
14 for function calls over a bi-directional interface
15 15. This interface is hardware dependent having the
following minimal requirements. The interface 14 and
15 between the OS and SPP provides a path which permits
the OS to pass data to the SPP and synchronously receive
result data generated by the SPP. Further, this interface
20 allows repeated uses of the function call. Numerous
types of data exchange mechanisms suitable for use by
the present invention are included in numerous types
of computer systems, as is well known in the art.

While it is not necessary for this interface
25 to be synchronous for all implementations, to do so allows
the interface to be implemented as a function call.
The minimum requirements for this interface is to provide
a path and mechanism between the OS and SPP to exchange
data.

30 In accordance with the invention, MCP 11 and
TCU microcode 13 include a TCU_EXCHANGE_FEATURES function
16 providing an exchange protocol between MCP and TCU
microcode that facilitates phasing in features that depend
on particular MCP and TCU microcode functionality. The
35 form of the communication path between the OS and SPP
(MCP 11 and TCU microcode 13) is a function call by the
OS utilizing Hardware Support For Function Calls 14 in

1 a manner to be described. When the OS 11 calls this
function, the SPP microcode 13 is notified and obtains
the data represented by the parameters via the interface
14. The SPP microcode 13 processes the data and provides
5 the result data for the call. A prototype and further
details of the function 16 will be described below.

The OS 11 and SPP microcode 13 include respective
exchange control portions 20 and 21 for controlling the
exchange of feature information in a manner to be
10 described in further detail. The OS 11 also includes
a report portion 22 that receives the result of the
exchange of feature information.

The OS 11 includes a FEATURES list 23 that
comprises a list of feature word bit masks supported
15 by the OS. This is hardcoded data. The FEATURES list
23 includes features bit masks 24 which will be further
described below. A required/optional indication 25 is
included indicating if a feature is a required feature
or an optional feature.

20 In a similar manner, the OS 11 includes a
SUPPORTEDFEATURES list 30 of supported features bit masks
representing the features that are mutually supported
by the OS 11 and SPP microcode 13. SUPPORTEDFEATURES
list 30 includes features bit masks 31 with a required/
25 optional indication 32 indicating if each supported
feature is required or optional.

The SPP microcode 13 includes a FEATURES list
40 which is a list of feature word bit masks supported
by SPP microcode 13. This is hardcoded data.
30 Accordingly, the FEATURES list 40 includes features bit
masks 41 with required/optional indicators 42.

The SPP microcode 13 includes a SUPPORTEDFEATURES
list 50 which is a list of supported features bit masks
providing indications of features mutually supported
35 by OS 11 and SPP microcode 13. Accordingly, the
SUPPORTEDFEATURES list 50 includes features bit masks
51 as well as the required/optional indicators 52.

1 Although elements 23, 30, 40 and 50 are described
as lists, it is appreciated that any suitable data
structure may be utilized, e.g., an array or a set of
defines. The term list is used in the claims to denote
5 any such suitable data structure.

The features are defined as follows.

Features provided and used by both the OS and
SPP microcode environments have one or more of the
following characteristics.

- 10 1. The feature may be designed as a client/server
interface such that one environment provides
a service used by the other environment.
The determination of whether the feature
15 is required or optional is made with respect
to the client environment. That is, if the
client can operate without the service
(feature) provided by the server, then the
feature can be made optional. Otherwise
the feature is required.
- 20 2. The feature may be designed such that the
format of an existing data structure which
is shared between the two environments is
modified when the feature is enabled. If
both environments can operate using either
25 the old or new formats, the feature may be
defined as optional. Otherwise the feature
is required.
- 30 3. The feature is designed such that when
enabled, both environments do not interact
to support it. If the feature can be designed
such that an alternate mode of operation
is used if the feature is not available in
both environments, then it may be defined
as optional. Otherwise the feature is
35 required.

An example of a required feature is as follows.
The SPP is modified such that a particular class of

1 function calls requires the data to be accompanied with
additional control information. The modification is
such that the SPP hardware automatically "consumes" the
control data making the data's existence a requirement
5 for all such function calls by the OS. The OS and SPP
microcode would add this as a required feature. If this
new SPP were installed in a computer system without
updating the OS (i.e., the OS would not have the new
feature defined), the function calls by the OS to the
10 SPP would not contain the necessary control data. The
possible combinations of OS software and SPP microcode
and resulting actions are as follows.

- 15 1. If the OS software version does not recognize
the new feature and the SPP hardware/microcode
comprises the old hardware and microcode
wherein the feature is not defined, both
OS and SPP behave as before.
- 20 2. If the OS software version does not recognize
the new feature but the SPP hardware/microcode
has been upgraded to the new hardware and
microcode wherein the feature is defined,
then after exchanging features, the new
feature is not recognized by the OS and
therefore ignored. The SPP, however, returns
25 an error because the feature requires
cooperation by the OS.
- 30 3. If the OS software version has been upgraded
to recognize the new feature where the
function calls in the particular class will
contain additional control data but the SPP
hardware/microcode is the old hardware and
microcode wherein the feature is not defined,
then after exchanging features, the new
feature is not recognized by the SPP and
35 therefore ignored. The OS, however, returns
an error because the feature requires
cooperation by the SPP.

- 1 4. If the OS software version has been upgraded
to recognize the new feature where the
function calls in the particular class will
contain additional control data and the SPP
5 hardware/microcode has been upgraded to the
new hardware and microcode where the feature
is defined, then after exchanging features,
the new feature is recognized by both the
SPP and OS and therefore used.

10 An example of an optional feature is as follows.
The SPP microcode is modified to provide a new function
call that returns statistics relative to performance.
This feature falls under the client/server model. The
OS determines that the statistical information provided
15 by the new function call is useful but not critical and
therefore dictates that the feature will be considered
optional. The OS is modified to recognize the new feature
and if present will periodically perform the function
call (if available) to gather and report the performance
20 statistics. Older versions of the SPP microcode would
not report this feature. The possible combinations of
OS software and SPP microcode and resulting actions are
as follows.

- 25 1. If the OS software version does not recognize
the new feature and the SPP hardware/microcode
has the old microcode in which the feature
is not defined, both the OS and SPP behave
as before.
- 30 2. If the OS software version does not recognize
the new feature but the SPP hardware/microcode
has been upgraded to the new microcode wherein
the feature is defined, then after exchanging
features, the new feature is not recognized
by the OS and therefore ignored. The SPP
35 sees that the OS does not use (i.e.,
recognize) the new feature. No error is
returned by the SPP since the SPP plays the

1 server role in this case. That is, whether
or not the function is used does not matter
to the SPP.

5 3. If the OS software version has been upgraded
to recognize the new feature but the SPP
hardware/microcode includes the old microcode
wherein the feature is not defined, then
after exchanging features, the new feature
is not recognized by the SPP and therefore
10 ignored. The OS sees that the SPP does not
support the feature. Since the OS treats
this as optional, it will not use the
interface to report statistics.

15 4. If the OS software version is upgraded to
recognize the new feature and the SPP
hardware/microcode has been upgraded to the
new microcode wherein the feature is defined,
then after exchanging features, the new
feature is recognized by both the SPP and
20 OS. The OS will therefore use the feature
to report statistics.

To facilitate the exchange of supported features
between the OS and SPP microcode, features are represented
in one or more bit masks. Each bit in the mask represents
25 a unique feature. If the bit is on (i.e., =1), then
the feature is either supported (i.e., provided by the
environment) or in the client/server case, supported
(server) or used (client). If the bit is off (i.e., =0),
then the feature is not supported or used.

30 The following rules are utilized for assigning
a new feature which requires both OS and SPP development.

1. The feature is assigned a unique number.
Features are numbered sequentially starting
with one.
- 35 2. The feature is determined to be either
required or optional. If the feature is
optional, then an alternate mode of operation

1 is developed along with the feature's mode
of operation such that the system will
function in the alternate mode when the
feature is not mutually supported.

5 3. When the feature is developed, its number
and required/optional information is embedded
in the software and/or microcode for use
during the exchange process.

During the exchange process, one or more bit
10 masks are exchanged. The width of the bit mask is system
dependent but should be as wide as a standard system
"word" minus one bit (Bit0 is reserved as a flag for
indicating when the last mask word has been exchanged).
For example, for system words which are 8 bits wide,
15 7 features can be represented per mask word. Feature
1 is represented by bit1 of Word1, feature2 by bit2 and
so forth.

If the number of features exceeds a system word,
multiple words are used. The feature number (Feature#)
20 can be expressed in terms of the mask word number (Word#)
and bit number in the mask word (Bit#). Feature and
word numbers start at 1. The relationship between these
numbers can be expressed as follows, where B =
BITS_PER_SYSTEM_WORD. *and bit# ranges from 1 to (B-1)*

25 Feature# = (Bit# + ((B - 1) x (Word# - 1))).

The following equations provide the bit and word
numbers in terms of the feature number.

Word# = (Feature# + (B - 1) - 1) DIV (B - 1).

Bit# = Feature# - ((B - 1) x (Word# - 1)).

30 For example, for systems with 8 bit words, feature
number 22 is represented in Word4, Bit1:

Word# = (22 + 8 - 1 - 1) DIV (8 - 1) = (28/7) = 4.

Bit# = ~~22 - ((8-1) x (4-1)) = 22 - (7x3) = 1~~
22 MOD (8-1) = 22 MOD 7 = 1

It is appreciated that the same procedure is
35 utilized for determining word and bit numbers for systems
with the 48 bit words indicated above with respect to
Figure 1.

1 The Hardware Support For Function Calls 14 is
the interface preferably utilized by the exchange function
TCU_EXCHANGE_FEATURES 16 for exchanging feature
information between the MCP 11 and the TCU microcode 13.

5 Referring to Figures 2(a)-2(c), with continued
reference to Figure 1, Figure 2(a) sets forth the MCP
procedure declaration for TCU_EXCHANGE_FEATURES function
while Figure 2(b) defines the parameters thereof.
TCU_EXCHANGE_FEATURES is an MCP procedure which uses
10 the Hardware Support For Function Calls 14 interface
and provides an interface between the MCP and TCU
microcode for exchanging a bit mapped list of supported
features.

15 The parameter WORDNUM is defined as the word
number of MCP-understood or MCP-supported features
indicated in MCPTCUFEATURES. The MCP 11 passes the Word#
in this parameter, each Word# passing 47 feature bits.

20 With respect to MCPTCUFEATURES, each of bits
1...47 in this word corresponds to a particular feature
supported by the MCP 11 or TCU microcode 13. The MCP
11 sets a feature bit to 1 if and only if the feature
is supported by the MCP 11 or the feature is a TCU
microcode feature that the MCP understands.

25 The parameter LASTCALL is set to TRUE if and
only if this is the last call of TCU_EXCHANGE_FEATURES
that the MCP will make.

30 TCU_EXCHANGE_FEATURES utilizes the Hardware
Support For Function Calls 14 interface. The parameters
passed over this interface are set up as illustrated
in Figure 2(c). TCU_EXCHANGE_FEATURES returns the BOOLEAN
value of the Result Word returned by the TCU microcode
13 via the interface.

35 The first MCP/TCU feature is assigned to the
first feature word, bit1. As new features are added,
bits are assigned at the next highest available bit of
the last MCPTCUFEATURES word. A single call to this
interface allows the exchange of 47 unique features.

1 If more than 47 features are defined, multiple calls
are made by specifying WORDNUM = 2 for features 48-94,
WORDNUM = 3 for features 95-141 and so forth. Using
the equations given above, the feature number is defined
5 by (Bit# + 47(WORDNUM - 1)). The last MCPTCUFEATURES
word sent specifies LASTCALL = TRUE.

When a feature bit is assigned, it is
characterized by both the MCP and TCU microcode as either
optional or required. Required features must be supported
10 by both the MCP and TCU microcode. If a required feature
is not mutually supported, the MCP will DEADSTOP the
system. Optional features need not be supported by both.
If an optional feature is not supported by both the MCP
and TCU microcode, the feature is not used. For each
15 call to this interface, the TCU microcode returns its
corresponding MCPTCUFEATURES word as specified by WORDNUM.

Thus it is appreciated that this MCP to TCU
function interface is defined to support feature
coordination.

20 Referring to Figures 3(a) and 3(b) with continued
reference to the preceding figures, a flow chart is
illustrated describing how the TCU_EXCHANGE_FEATURES
interface 16 is used during system initialization, IOM
reconfiguration and microcode load by both the MCP and
25 TCU microcode. The initial value of <n> is "1". In
the flow chart, comments are preceded by "&".
Additionally, a data word followed by "&<k>[:1]" is
a bit set operation. It sets bit to <k> where k
is 0 or 1. The blocks of the flow chart illustrated
30 in Figure 3(a) are identified by reference numerals
100-104, respectively, and the blocks of the flow chart
illustrated in Figure 3(b) are identified by reference
numerals 110-114, respectively. In branching blocks
102-104, 110, 111 and 113, the left hand branch is
35 denoted by the suffix "a" and the right hand branch is
denoted by the suffix "b". Blocks 100 and 110-114
describe actions occurring in the MCP environment. Blocks

1 101-104 describe actions occurring in the TCU environment.

In block 100, the MCP calls the
TCU_EXCHANGE_FEATURES interface with the parameters as
indicated. The exchange information is transferred to
5 the TCU via the Hardware Support For Function Calls 14
and the path 15 (Figure 1). The illustrated set up of
parameters was discussed above with respect to Figure 2.
The LASTCALL parameter bit is set in the least significant
bit of PARAM2 as indicated. Dotted arrow 106 indicates
10 the MCP to TCU communication path 14 and 15 (Figure 1).

In block 101 the TCU microcode receives the MCP
data which is processed as indicated in the blocks
102-104. In blocks 103b and 104b an ERROR RESULT may
be bit set as indicated, or in block 104a a NORMAL RESULT
15 may be bit set as indicated. The RESULT word
TCU_FEATURE_WORD<N> is returned to MCP as indicated by
dotted arrow 107 at the bottom of Figure 3(a) and the
top of Figure 3(b). The TCU to MCP communication is
effected along communication path 15 (Figure 1).

20 With continued reference to Figure 3(b), in blocks
110 and 111 the MCP either verifies that all of its
required features are supported by the TCU microcode
or detects unsupported features and deadstops the system.
In block 112, a global feature list is established and
25 in blocks 113 and 114, preparation is made for additional
calls or termination of the process. Block 114 returns
to block 100 of Figure 3(a) utilizing the label START.

The specific descriptions with respect to Figures
1-3 above were provided with respect to the specific
30 MCP and TCU environments. A more generic description
of the invention is now provided in terms of the OS and
SPP environments. The following is a prototype of the
generic function.

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1 Referring to Figure 4, a pseudo code description
of the feature exchange mechanism using the
EXCHANGE_FEATURES function is illustrated. This mechanism
would be invoked during system initialization prior to
5 use of any of the defined features. The following
conventions are used in Figure 4.

1. Labels are shown in bold characters.
2. The described activity is either occurring
10 in the OS environment or in the SPP
environment. The environment is indicated
by use of [OS] or [SPP].
3. Local variables belonging to the [OS]
environment use the suffix "_OS". Similarly,
variables in the [SPP] environment use "_SPP".
- 15 4. Comments are preceded by "%".
5. NEQ represents Not Equal and is a bitwise
comparison operation ignoring Bit0.
6. AND represents a bitwise AND operation or
when used in a conditional test, a logical
20 AND operation.
7. A data word followed by "<k>[:1]" is
the above mentioned bit set operation. It
sets bit to <k> where k is 0 or 1.

It is appreciated that the functionality of Figure
25 4 closely tracks that of Figures 3(a) and 3(b). The
LOOP section of Figure 4 corresponds to blocks 100-103
of Figure 3(a). The CHECK_LAST section of Figure 4
corresponds to block 104 of Figure 3(a). The RETURN
section of Figure 4 corresponds to Figure 3(b). The
30 feature list is implemented as the array FEATURES_OS
in the MCP and FEATURES_SPP in the SPP.

After performing the operations, the OS has either
faulted due to a feature mismatch or has completed the
exchange of all feature words. If a fault did not occur,
35 both the OS and SPP have identical records of which
features are mutually supported in their respective
arrays. If an optional feature is not supported, it

1 will not be used and an alternative mode of operation
may be effected.

It is appreciated with respect to Figures 1 and
4 that the FEATURES_OS array is an implementation of
5 the FEATURES list 23 and the hardcoded bit masks are
stored at 24. The SUPPORTEDFEATURES_OS array is an
implementation of the SUPPORTEDFEATURES list 30 with
the bit masks stored at 31. The FEATURES_SPP array is
an implementation of the FEATURES list 40 with the
10 hardcoded bit masks stored at 41. The
SUPPORTEDFEATURES_SPP array is an implementation of the
SUPPORTEDFEATURES list 50 with the bit masks stored at
51. The SPPFEATURES_OS is returned as report 22.

Bit masks are utilized to facilitate the
15 comparison operation. The use of bit masks is not,
however, a requirement. Other known feature indication
storage arrangements, such as any bit map arrangement,
could be utilized to the same effect.

Another example of two software entities that
20 may utilize the invention are two independent processes
running within the same computer system controlled by
the same OS. Any two software processes which are capable
of using an InterProcess Communication (IPC) mechanism
to implement interface 14-15 may use this invention.

25 The above described embodiment was explained
in terms of mutually supported features. However,
features which are not mutually supported could be
included for reporting purposes. That is, the OS could
obtain and report on SPP features which the OS does not
30 need to support. These features would be considered
optional.

Each of, or at least one of, the software entities
maintains/constructs a list of features supported by
both. The bits representing optional features may be
35 dynamically referenced to determine whether to use the
feature or to effect the alternate mode.

While the invention has been described in its

- 1 preferred embodiment, it is to be understood that the
words which have been used are words of description rather
than limitation and that changes may be made within the
purview of the appended claims without departing from
5 the true scope and spirit of the invention in its broader
aspects.